PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification: Not classified

A2

(11) International Publication Number: WO 93/08677

(43) International Publication Date: 13 May 1993 (13.05.93)

(21) International Application Number: PCT/US92/07228

(22) International Filing Date: 26 August 1992 (26.08.92)

(30) Priority data:
785,140 30 October 1991 (30.10.91) US

(71) Applicant: ALLERGAN, INC. [US/US]; 2525 Dupont Drive, P.O. Box 19534, Irvine, CA 92713-9534 (US).

(72) Inventors: GWON, Arlene, E. ; 8 Trafalgar, Newport Beach, CA 92660 (US). BERNS, Michael, W. ; 3112 Via Colinas, Trabuco Canyon, CA 92679 (US).

(74) Agents: LAMBERT, Howard, R. et al.; Allergan, Inc., 2525 Dupont Drive, Post Office Box 19534, Irvine, CA 92713-9534 (US).

(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE).

Published
With declaration under Article 17(2)(a).
Without classification and without abstract; title not checked by the International Searching Authority.

(54) Title: METHOD OF LASER PHOTOABLATION OF LENTICULAR TISSUE FOR THE CORRECTION OF VISION PROBLEMS

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LU	Luxembourg
MC	Monaco
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SK	Slovak Republic
SN	Senegal
SU	Soviet Union
TD	Chad
TG	Togo
UA	Ukraine
US	United States of America
VN	Viet Nam

METHOD OF LASER PHOTOABLATION OF LENTICULAR TISSUE FOR THE CORRECTION OF VISION PROBLEMS

BACKGROUND OF THE INVENTION:

Field of the Invention:

The present invention relates generally to the field of photoablation of ocular tissue to correct vision deficiencies and treat other vision-impairing ocular problems, and, more particularly, to treatment of the natural ocular lens.

Background Discussion:

Historically, and until only a few decades ago, eye-glasses (i.e., spectacles) were exclusively used for most correctable vision deficiencies, including, for example, hyperopia (wherein incident parallel rays of light converge to focus behind the retina), myopia (wherein incident parallel rays of light converge to a focus in front of the retina), and astigmatism (a defect in vision ordinarily caused by irregularities in the cornea). However, in about the 1940s, contact lenses started being used as a viable alternative, at least for many individuals, to the use of spectacles for correcting vision deficiencies, and provided--often at a cost of some discomfort--freedom from many annoyances and appearance problems associated with the wearing of spectacles.

Another method for treating some types of problems causing vision problems was introduced by Dr. Peter Ridley just after the close of World War II. This new (although there is some evidence that it had been tried

several hundred years ago) method involved the replacement of a diseased natural ocular lens, for example, a natural lens which had been clouded because of cataract, with a plastic artificial or prosthetic intraocular lenses (IOL). Such lens extraction and IOL implantation is now a commonly-performed surgical procedure and is credited with saving the sight of many individuals who were or would have become blind.

Vision correction can now be achieved on some patients, especially those with myopia, by a surgical procedure on the cornea called radial keratotomy (RK). In an RK procedure, several slits, for example about five, are made radially inwardly toward the optical axis from the peripheral edge of the cornea. These radial slits enable the cornea to flatten out a bit, thereby decreasing the curvature of the cornea. Candidates for RK procedures are typically near-sighted individuals who cannot or who do not want to wear either spectacles or contact lenses.

Corneal onlays or implants, which may be constructed of synthetic materials or from donor corneas, are surgically attached to or implanted into patients' eyes, are also useful to enhance vision in patients whose corneas have been damaged and/or scarred by corneal diseases, such as ulcers or cancer, or by injury to the cornea.

Due to shortcomings associated with RK surgery and a desire to provide vision correction to many individuals without the necessity for those individuals to wear spectacles or contact lenses, considerable research and development has been directed over the past several years to apparatus and techniques for reshaping the anterior (forward) surface of the cornea. Excimer lasers--lasers operating in the ultraviolet

(UV) region of less than about 200 nanometers wavelength--have thus now been used to selectively ablate regions of the cornea to resculpt the cornea of patients in a manner correcting certain vision problems. For example, regions of the cornea around its optical axis are photoablated to a greater depth than peripheral regions of the cornea, thereby decreasing the curvature of the cornea to correct myopia. In contrast, photoablation of the cornea is concentrated near the periphery of the cornea to increase the curvature of the cornea and thereby correct for hyperopia. In a related manner, astigmatism can be corrected by selectively varying the rate of laser photoablation of an astigmatic cornea in a manner providing an appropriate vision correction. In this regard, U.S. patent No. 4,784,135 to Blum, et al., discloses a method for removing biological tissue by irradiation the tissue with UV radiation; while, for example, U.S. patent Nos. 4,665,913; 4,669,466; 4,718,418; 4,721,379; 4,729,372; 4,732,149; 4,770,172; 4,773,414; and 4,798,204 to L'Esperance disclose apparatus and methods for laser sculpting of corneal tissue to correct vision defects. In addition, U.S. patent No. 4,842,782 to Portney, et al. and No. 4,856,513 to Muller (as well as one or more of the above-cited L'Esperance patents) disclose masks useful for selectively controlling the laser beam intensity or total laser beam energy to different regions to thereby enable selective corneal ablation to effect the desired vision correction. Various of the above-cited patents to L'Esperance also disclose methods for determining the required laser ablation profile for the cornea; for example, patent No. 4,995,913 discloses computer

mapping of the cornea and computer-controlled scanning of the cornea by the laser beam.

In spite of reported short-term medical successes--both in clinical testing in the United States and in use in unregulated foreign countries--with laser photoablation of corneal tissue to correct vision deficiencies, the verdict is still not in concerning the long-term effects and efficacy of corneal laser photoablation. In particular, questions have been raised whether over a long term the vision correction initially provided by photoablation of the cornea will remain effective because of the normal regrowth of the removed epithelium layer of the cornea over the ablated area. In this regard, there seems to be at least some natural tendency for the epithelium layer to regrow in a manner that, in time, the pre-ablation contour of the cornea may be reestablished or sufficiently so that vision re-correction is required. An ancillary question is, therefore, how many times and how frequently can a laser photoablation process be repeated. Also there have been reports of haze forming on the cornea after photoablation; although this appears to be a relatively transient phenomena--lasting only a few months and ordinarily not too bothersome to the patient--at the present there has been insufficient post-ablation time on any patients to determine long term effects. Moreover, it appears that there may be a maximum diopter change--around five diopters--that can presently be effectively and predictably made by corneal photoablation. Still further, at least at present, the laser ablation of corneal tissue is extremely painful to the patient on which the surgical procedure is performed.

Further with respect to laser photoablation of the cornea, it should be appreciated that although in so doing the cornea is sculpted in a manner correcting vision, it is frequently the case that the cornea is not itself responsible for the vision problems being corrected. As an illustration, myopia may more likely be caused by an increase in lens size, usually as a natural effect of the human ageing process, of the natural lens of the eye (located posteriorly of the cornea). Other vision defects or deficiencies may also originate at the natural lens, while the associated cornea may itself be in a normal condition.

For these and other reasons, and for the reason that because the lens is closer to the retina than is the cornea, less material would have to be removed from the lens to achieve a similar vision correction, the present inventor has determined that it would often be preferable to reprofile the natural lens over reprofiling the cornea. Such natural lens reprofiling would eliminate many of the concerns presently raised about corneal photoablation and may result in reduced risks to patients, and since the lens has no nerve supply, the procedure should result in no sensation of pain to the patient. It is, therefore, a principle objective of the present invention to provide a method for laser ablation of selected regions of the natural lens in order to correct vision problems and to correct problems, such as incipient cataract, on the lens.

SUMMARY OF THE INVENTION:

According to the present invention, there is provided a method for the laser photoablation of ocular lens tissue, the method comprising the steps of

determining the region of the lens tissue to be photoablated, and directing a pulsed laser beam at such region with an amount of energy effective for photoablating the region without causing substantial damage to surrounding tissue regions. Preferably, the laser is a Nd:YLF laser having an operating frequency in the infrared spectrum and more preferably having an operating frequency of about 1053 nanometers. The laser preferably has a repetition rate of between about 1 and about 1000 Hertz, and more preferably about 1000 Hertz; and operates with a pulse width of between about 1 femtosecond and about 1 millisecond and, more preferably, about 60 picoseconds. Moreover, the laser preferably operates at an energy level of between about 1 nanojoule and about 50 millijoules per pulse and, more preferably, about 30 microjoules. Still further, the laser preferably operates with a beam spot diameter of between about 1 micron and about 100 microns and, more preferably, with a beam spot diameter of about 20 microns. The laser preferably operates with a zone of effect of less than about 200 microns and, more preferably with a zone of effect of less than about 50 microns.

In accordance with one embodiment of the invention, a method is provided for the laser photoablation of ocular lens tissue for the correction of myopia, hyperopia or presbyopia. In this case, the method comprises the steps of determining the region of the lens tissue to be photoablated, calculating the amount of lens tissue to be photoablated from the determined region; and directing the pulsed infrared laser beam at the region with an amount of energy effective for photoablating the calculated amount of lens tissue in the determined region without causing

substantial damage to lens tissue surrounding such region.

In another embodiment of the invention, a method is provided for the laser photoablation of ocular lens tissue for the removal of incipient cataract, the method comprising the steps of determining the region of the lens tissue to be photoablated so as to remove the incipient cataract; calculating the amount of lens tissue to be photoablated from the determined region so as to remove the incipient cataract; and directing the pulsed infrared laser beam at the region with an amount of energy effective for photoablating the calculated amount of lens tissue in the determined region so as to remove the incipient cataract without causing substantial damage to lens tissue surrounding such region.

BRIEF DESCRIPTION OF THE DRAWINGS:

The present invention can be more readily understood by a consideration of the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a longitudinal cross sectional drawing of a representative eye showing, in simplified form, the cornea, iris, natural lens and retina, and showing the manner in which an image is focused on the retina in a normal eye.

FIG. 2 is an enlarged, longitudinal cross sectional drawing of a normal lens showing, in simplified form, its composition; and

FIG. 3 is a simplified, longitudinal cross sectional drawing--similar to FIG. 1--showing the manner in which the natural lens has regions thereof photoablated using, for example, a Nd:YLF laser operating at a frequency of about 1053 nanometers and operating at a repetition rate of about 1000 pulses per second, FIG. 3a showing the manner in which internal regions of the lens are photoablated for the purpose of correcting myopia, hyperopia or presbyopia, and FIG. 3b showing the manner in which generally surface regions of the lens are photoablated to remove incipient cataract.

In the various FIGs. identical elements and features are given the same reference number.

DETAILED DESCRIPTION OF THE INVENTION:

There is shown in FIG. 1, in greatly simplified diagrammatic form, a longitudinal cross sectional drawing of a typical, normal eye 10, which is generally symmetrical about an optical axis 12. Shown comprising eye 10, and in order from the front of the eye to the back, is a cornea 14, an iris 16, a natural lens 18 and a retina 20. In a normal eye, light from an object 22 is refracted by cornea 14 and lens 14 so as to form an image 24 on retina 20 (iris 16 being shown having an open central aperture 26 permitting light to pass through to the lens).

Shown more particularly in FIG. 2 (but still in greatly simplified form), lens 18 is a biconvex, somewhat flexible structure which is suspended behind iris 16 and is connected to a peripheral cilary body 30 of eye 10 by zonal fibers (zonules) 32. Since lens 18

is avascular, its pathology is more simple than most other tissues of the body; primary inflammation processes do not occur and neoplastic growths in lens 18 are unknown. However, trauma or injury to lens 18 results in passive and degenerative changes in the lens with consequent opacification.

Focusing of lens 18, which functions to transmit and refract light to retina 20, is (assuming the lens is in its normal, youthful condition) by contraction and relaxation of zonal fibers 32. In the relaxed state of fibers 32, lens 18 assumes its maximum convex curvature and thickness; as tension in zonal fibers increases, lens 18 is stretched and its convex curvature and thickness is decreased. By this mechanism, called accommodation, the shape of lens 18 is physically varied in a manner causing images 22 to be correctly focused on retina 20 as the distance, D, between object 22 and cornea 14 changes between far and near.

Lens 18 consists of about 65 percent water and about 35 percent protein (known as crystallins), along with traces of minerals. Lens 18 is avascular, containing no blood vessels, and has no nerve supply, and comprises a thin, transparent capsule or bag 34, a subcapsular epithelium layer 36, a cortex 38 of soft fibres and a harder, dense nucleus 40 at the center. During development of lens 18, surface ectoderm invaginates to form the lens vesicle. The posterior cells of the lens vesicle then elongate to form the primary lens fibres, which obliterate the cavity of the vesicle and abut on the anterior (forward) epithelium layer 36. This process is completed early in fetal development. Subsequently, secondary lens fibres are added throughout life by the elongation and

differentiation of epithelial cells circumferentially at the equator of lens 18. The net result is the progressive internalization of previously-formed fibers. The older fibers are always found toward nucleus 40 and the younger fibers toward cortex 38.

Lens 18 continues to grow throughout an individual's life in a process similar to that in which the epidermal tissue of the skin renews itself. However, unlike the skin where old cells are continually cast off from the surface, older lens cells accumulate centrally and cannot be cast off. The net result is a progressive growth of lens 18 with age, associated with a decrease in elasticity and accommodative ability. The result is that the most common degenerative condition of lens 18 is presbyopia, a condition in which loss of elasticity of the lens results in the inability of eye 10 to focus sharply for near vision, such that most individuals by about the age of forty require some visual assistance, for example, that provided by spectacles, contact lenses or RK surgery.

Another common degenerative condition of lens 18 that is generally associated with aging is cataract, which is generally defined as any opacity in the lens. In the case of cataract, the extent of disability depends upon the location and severity of the opacity. Thus, a relatively small posterior (i.e., rearward) subcapsular cataract may be visually incapacitating because it is situated near the nodal point of the dioptric system, while peripheral opacities that do not impinge on optical axis 12 may cause little visual inconvenience. In general, patients initially complain of a visual disturbance, then a diminution of vision and finally a complete failure of vision. For small

lens opacities and early disturbance or diminution of vision there is no proven therapeutic modality (i.e., treatment). Ophthalmologists have long considered removal of lens 18 as the only treatment for cataract. At present, the most commonly performed operation is an extracapsular cataract extraction with intraocular lens implantation, the objective of the surgical procedure being to remove as much of the lens as possible with subsequent optical device correction. The concept or selective removal of a small opacity or sections of the lens was not heretofore considered nor would it have been technically possible.

THE PRESENT INVENTION:

The present invention relates to methods to treat presbyopia, refractive errors, and cataract by means of focusing high power pulse laser photoablation of lens opacities and selected normal lens fibers. A laser 50 (FIG. 3) which can advantageously be used for such purpose is preferably, but is not limited to, a quasi-continuous Nd:YLF picosecond laser which may be purchased as ISL Model 2001 MPL or 4001 CLS from Intelligent Laser Systems, Inc. of San Diego, California. In general, laser 50 produces a shock wave in the tissue at which its beam is focused, the shock wave expanding radially from the point of focus and disintegrating the target tissue (optical breakdown), thereby causing ionization of the medium and the formation of a plasma. This plasma is a gaseous state, formed when electrons are stripped away from their atoms in either a gas, liquid or solid. Once optical breakdown occurs, the plasma that is formed absorbs or scatters subsequent light in the

laser pulse, thereby acting as an effective shield protecting underlying structures. The quicker the laser pulses, the faster and more easily the plasma is created.

For the present photoablation procedure, laser 50 preferably has the following characteristics:

1. An operating frequency preferably in the visible and infrared (IR) spectrum; more preferably, about 1053 nanometers (nm).
2. A repetition rate preferably ranging from about one to about 1000 Hertz; more preferably, about 1000 pulses per second.
3. A pulse width preferably ranging from about 1 femtosecond to about 1 millisecond; more preferably, about 60 picosecond.
4. An energy level per pulse preferably ranging from about 1 nanojoule to about 50 millijoules; more preferably, about 30 microjoules.
5. A focused spot size (diameter) preferably between about 1 micron and about 100 microns; more preferably, about 20 microns.
6. A "zone of effect" preferably limited to between about 1 and about 200 microns with little collateral effect; more preferably, the zone of effect is limited to about 50 microns.

The procedure described hereinbelow for the laser photoablation of lens tissue ordinarily requires an initial ocular examination of the prospective patient, including refractive status, slit lamp biomicroscopy, and the measurement of axial length of lens 18 by standard applanation A-scan ultrasonography. The accommodative amplitude of lens 18 may be measured by

various techniques. For example, Adler (Moses RA. "Accommodation" In: Moses RA, Hart, MA Jr. eds. Adler's Physiology of the Eye, St. Louis, Washington, D.C., Toronto: The C.V. Mosby Co., Chapter 11, 1987:291-310--which is incorporated hereinto by specific reference) recommends that a convex lens be moved along the optical axis in front of the patient's eye, away from the eye, until a target object at a convenient distance just begins to blur--it is then assumed that accommodation is relaxed. The convex lens is then reduced (to a concave lens), or, alternatively, the target object is brought closer to the patient's eye until the target again starts to blur. The range between the "far" blur and the "near" blur or maximum plus (convex lens) to blur and maximum minus (concave lens) to blur is the range of accommodation in diopters.

For the treatment of presbyopia, the amount of lens thickness to be ablated can be calculated in two ways:

1. Based upon Normative Charts of lens thickness and accommodative amplitude with age:
Using the ultrasound data on saggital lens length with age by Rafferty (Rafferty, N. S. "Lens Morphology" In: Maisel, H., ed. The Ocular Lens. Marcel Dekker, Inc. New York and Basel. 1985:1-15, 52-60--which is incorporated hereinto by specific reference) and the accommodative amplitude at a given age, as shown, by way of example, in Duane's Table (Borish, Irvin M. "Accommodation", Clinical Refraction, The Professional Press, Inc., Chicago, 1975, 3rd Ed., Vol. 1, p 170--which is incorporated hereinto by specific reference), the

amount of required lens tissue ablation is calculated by subtracting the desired accommodation amplitude from the patient's actual accommodation amplitude. By way of illustration, with no limitation being thereby intended or implied, a patient of age 60 has a lens thickness of 4.66 mm and an accommodation amplitude of 1.25 Diopters. To increase the patient's accommodative amplitude to that of a person of age 30 who has a lens thickness of 4.15 mm and an accommodative amplitude of 7.5 Diopters, .51 mm (4.66 mm minus 4.15 mm) of lens tissue from the patient's lens. This would represent an increase of approximately 6.25 Diopters (7.5 Diopters minus 1.25 Diopters) of accommodative amplitude. Since the maximal thickness change in the lens during accommodation is about 0.5 mm, this change should be sufficient to restore the presbyopic 60 year old patient to an accommodative state.

2. Based on the patient's measured lens thickness and amplitude of accommodation:
The amount of lens tissue to be ablated is calculated based on the work of Koretz and Handelman (Koretz, J.F., Handelman, G.H., "Model of the accommodation mechanism in the human eye" Vision Res. Vol. 22 1982:917-927--which is incorporated hereinto be specific reference). A two micron change in lens thickness corresponds to a 0.02 Diopter change in accommodation. Thus, if a patient's amplitude of accommodation measures 1.25 Diopters and it is desired to increase that to 5 Diopters (a change of 3.75 Diopters) the

amount of decrease in lens thickness required would be approximately 375 microns.

For the treatment of hyperopia, the amount of lens tissue to be ablated is calculated as described above for presbyopia. This will increase the amplitude of accommodation of the patient's lens to allow the hyperope to move the focus of distant objects up to his or her retina 20.

For the treatment of myopia, the amount of lens tissue to be ablated can be calculated based on the refractive status of the eye and the measured lens thickness as set forth above in paragraph 2.

PROCEDURE:

For the treatment of presbyopia and hyperopia, a beam 52 from a HeNe focusing laser 54 (FIG. 3a) is focused, by an associated lens or lens system 56, through cornea 14 (which is transparent to the focusing beam) and iris opening 26, to a region 56 to be photoablated by Nd:YLF laser 50 for correction of the specific vision problem under treatment. In this regard, it is preferred that the more centrally located, older cortical and/or nuclear fibers be ablated since the width of nucleus 40 (FIG. 2) remains relatively constant with age, whereas that of cortex 38 increases. Then, a laser beam 60 from Nd:YLF laser 50 is focused by an associated focusing lens or lens system 66 through cornea 14 (which is transparent to the laser beam) and iris opening 26, onto region 56 which is to be photoablated by the Nd:YLF laser beam. The amount of lens tissue to be ablated (i.e., decomposed) to achieve the desired vision correction

is determined in the manner described above. The optical zone (equatorial diameter) should be approximately equal to the diameter of nucleus 40 and the axial width (for example, about 510 microns). For treatment of myopia, it is preferred that region 56 be selected so that nucleus 40 and/or centrally located older fibers in cortex 38 are ablated using a smaller optical zone so as to decrease the curvature of an anterior (forward) surface 62 of lens 18. Such laser ablation of lens 18 to correct myopia, presbyopia and hyperopia may be termed "photorefractive phacoplasty" or "phototherapeutic phacoplasty."

For the treatment of cataracts (FIG. 3b), beam 52 from HeNe focusing laser 54 (FIG. 3) may be directly focused by lens or lens system 56 (with the beam passing through cornea 14 and iris opening 26) onto an area or region 64 of small lenticular opacity. Then beam 60 from Nd:YLF laser 50 is focused, by lens or lens system 62 onto area or region 64 and the laser is pulsed until the opacity is ablated (as determined, for example, by visual observation through cornea 12 and iris opening 26).

It is preferred that if opacity area or region 64 is adjacent to lens capsule 18 (FIG. 2), aiming beam 52 from HeNe laser 52 is focused more centrally to the opacity to account for shock wave expansion. Such treatment (i.e., photoablative removal) of incipient cataract, which is intended to delay or prevent full cataract surgery, including removal of lens 18 and the replacement thereof with an IOL, may be termed "phototherapeutic phacoablation" or "photo-therapeutic phacoectomy."

In either of the above-described treatments, application of photoablation beam 60 from Nd:YLF laser

50 produces the formation of gas bubbles at the site of optical breakdown by the focused beam within lens 18 (that is, at regions such as above-described regions 58 and 64). The formed gas bubbles are, however, usually reabsorbed within lens 18 within 24 to 48 hours and lens 18 remains optically clear.

Care is taken in the operation of Nd:YLF laser 50 not to rupture lens capsule 34 by expansion of laser shock wave. Moreover, if excessive bubbles are formed at the ablation site, as detected, for example, by viewing, with a slit lamp (not shown) the ablation region through cornea 14 and iris opening 26, the laser ablation procedure is discontinued and additional treatment is performed at a later date, for example, in one or two weeks.

By the method described above, the natural lens in an eye can be photoablated by pulsed energy from a laser--preferably a Nd:YLF laser--in a manner correcting myopia, presbyopia and hyperopia and in a manner removing incipient cataracts. Because the above-described laser-ablative procedures are relatively non-invasive (as compared, for example to laser photoablation of the cornea to correct vision problems or the surgical removal of a natural lens in the case of cataract) and because lens 18 is non-vascular and contains no nerve supply, no post-ablation inflammation or wound-healing problems are anticipated and the use of steroids--commonly used after corneal laser photoablation--is not indicated. Moreover, because of its structural nature, lens 18 is not expected to revert--with time--to its pre-ablative shape--as may be the case for laser-ablated corneas.

Although there are described above methods for laser photoablation of a natural lens for correcting

vision problems for the purpose of illustrating the manner in which the present invention can be used to advantage, it is to be understood that the invention is not limited thereto. Therefore, any and all modifications and variations which may occur to those skilled in the art are to be considered to be included within the scope and spirit of the claims appended hereto.

THE CLAIMS:

What is claimed is:

Claim 1. A method for the laser photoablation of ocular lens tissue, said method comprising the steps of:

a. determining the region of the lens tissue to be photoablated; and

b. directing a pulsed laser beam at said region with an amount of energy effective for photoablating said region without causing substantial damage to surrounding tissue regions.

Claim 2. The method as claimed in Claim 1, wherein said laser is a Nd:YLF laser.

Claim 3. The method as claimed in Claim 1, wherein said laser has an operating frequency in the infrared spectrum.

Claim 4. The method as claimed in Claim 3, wherein said operating frequency is about 1053 nanometers.

Claim 5. The method as claimed in Claim 1, wherein said laser has a repetition rate between about 1 and about 1000, and operates with a pulse width of between about 1 femtosecond and about 1 millisecond.

Claim 6. The method as claimed in Claim 1, wherein said laser has a repetition rate of about 1000 hertz and operates at a pulse width of about 60 picoseconds.

Claim 7. The method as claimed in Claim 1, wherein said laser has an energy per pulse of between about 1 nanojoule and about 50 millijoules.

Claim 8. The method as claimed in Claim 1, wherein said laser has an energy per pulse of about 30 microjoules.

Claim 9. The method as claimed in Claim 1, wherein said laser operates with a beam spot diameter of between about 1 micron and about 100 microns.

Claim 10. The method as claimed in Claim 1, wherein said laser operates with a beam spot diameter of about 20 microns.

Claim 11. The method as claimed in Claim 1, wherein said laser operates with a zone of effect of less than about 200 microns.

Claim 12. The method as claimed in Claim 1, wherein said laser operates with a zone of effect of less than about 50 microns.

Claim 13. A method for the laser photoablation of ocular lens tissue for the correction of myopia, hyperopia or presbyopia, said method comprising the steps of:

a. determining the region of the lens tissue to be photoablated;

b. calculating the amount of lens tissue to be photoablated from said determined region; and

c. directing a pulsed infrared laser beam at said region with an amount of energy effective for photoablating said calculated amount of lens tissue in said determined region without causing substantial damage to lens tissue surrounding said region.

Claim 14. The method as claimed in Claim 13, wherein said laser is a Nd:YLF laser having an operating frequency of about 1053 nanometers.

Claim 15. The method as claimed in Claim 13, wherein said laser has a repetition rate between about 1 and about 1000, and operates with a pulse width of between about 1 femtosecond and about 1 millisecond.

Claim 16. The method as claimed in Claim 13, wherein said laser has a repetition rate of about 1000 Hertz and operates with a pulse width of about 60 picosecond.

Claim 17. The method as claimed in Claim 13, wherein said laser has an energy per pulse of between about 1 nanojoule and about 50 millijoules.

Claim 18. The method as claimed in Claim 13, wherein said laser has an energy per pulse of about 30 microjoules.

Claim 19. The method as claimed in Claim 13, wherein said laser operates with a beam spot diameter of between about 1 micron and about 20 microns and a zone of effect of less than about 200 microns.

Claim 20. The method as claimed in Claim 13, wherein said laser operates with a beam spot diameter of about 20 microns and a zone of effect of less than about 50 microns.

Claim 21. A method for the laser photoablation of ocular lens tissue for the removal of incipient cataract, said method comprising the steps of:

a. determining the region of the lens tissue to be photoablated so as to remove said incipient cataract;

b. calculating the amount of lens tissue to be photoablated from said determined region so as to remove said incipient cataract; and

c. directing a pulsed infrared laser beam at said region with an amount of energy effective for photoablating said calculated amount of lens tissue in said determined region so as to remove said incipient cataract without causing substantial damage to lens tissue surrounding said region.

Claim 22. The method as claimed in Claim 21, wherein said laser is a Nd:YLF laser having an operating frequency of about 1053 nanometers.

Claim 23. The method as claimed in Claim 21, wherein said laser has a repetition rate between about 1 and about 1000, and operates with a pulse width of between about 1 femtosecond and about 1 millisecond.

Claim 24. The method as claimed in Claim 21, wherein said laser has a repetition rate of about 1000 Hertz and operates with a pulse width of about 60 picosecond.

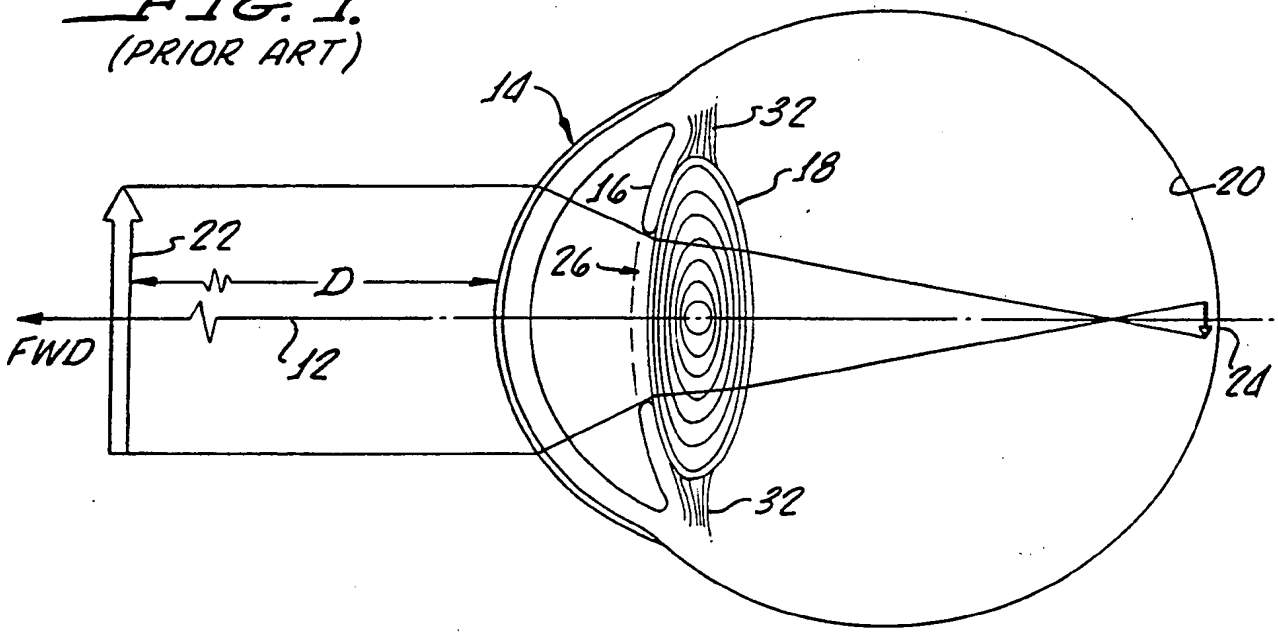
Claim 25. The method as claimed in Claim 21, wherein said laser has an energy per pulse of between about 1 nanojoule and about 50 millijoules.

Claim 26. The method as claimed in Claim 21, wherein said laser has an energy per pulse of about 30 microjoules.

Claim 27. The method as claimed in Claim 21, wherein said laser operates with a beam spot diameter of between about 1 micron and about 20 microns and a zone of effect of less than about 200 microns.

Claim 28. The method as claimed in Claim 21, wherein said laser operates with a beam spot diameter of about 20 microns and a zone of effect of less than about 50 microns.

FIG. 1.
(PRIOR ART)



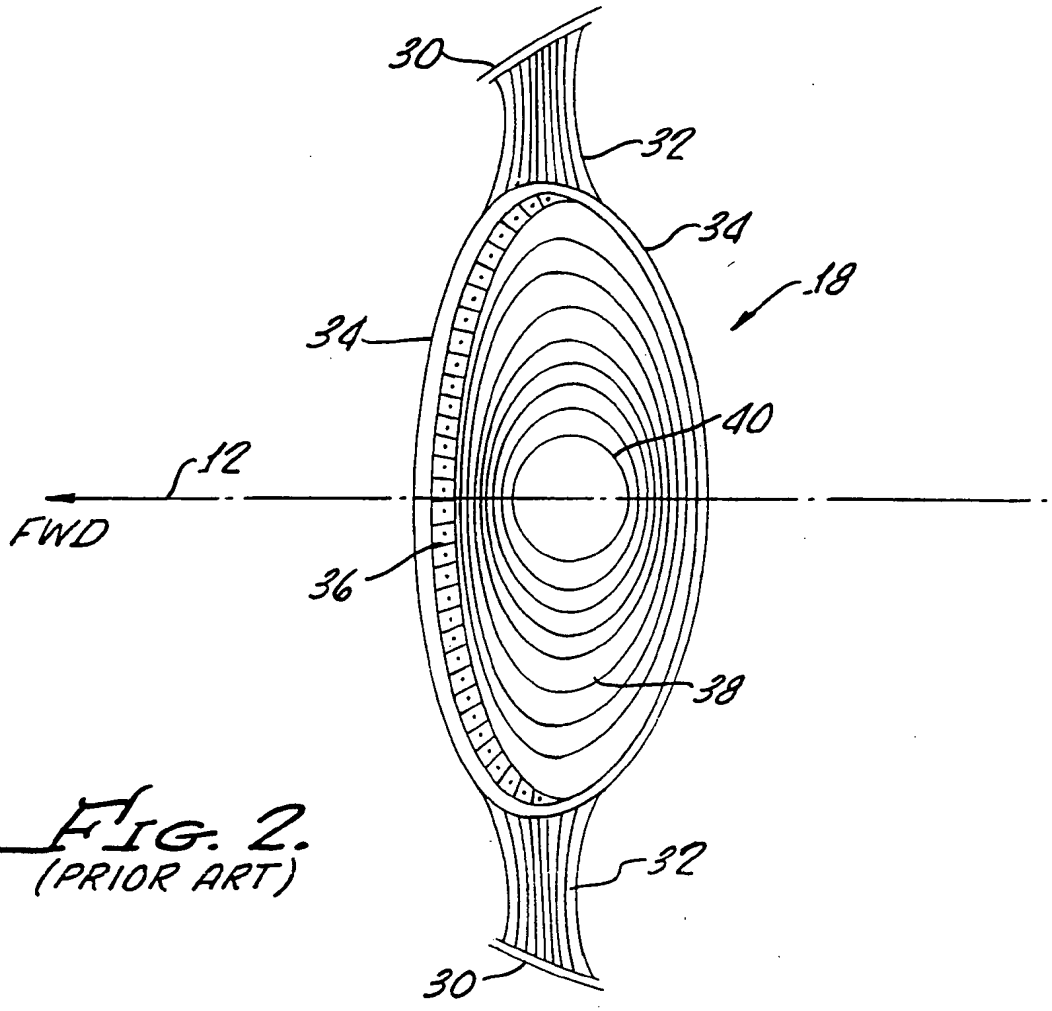


FIG. 2.
(PRIOR ART)

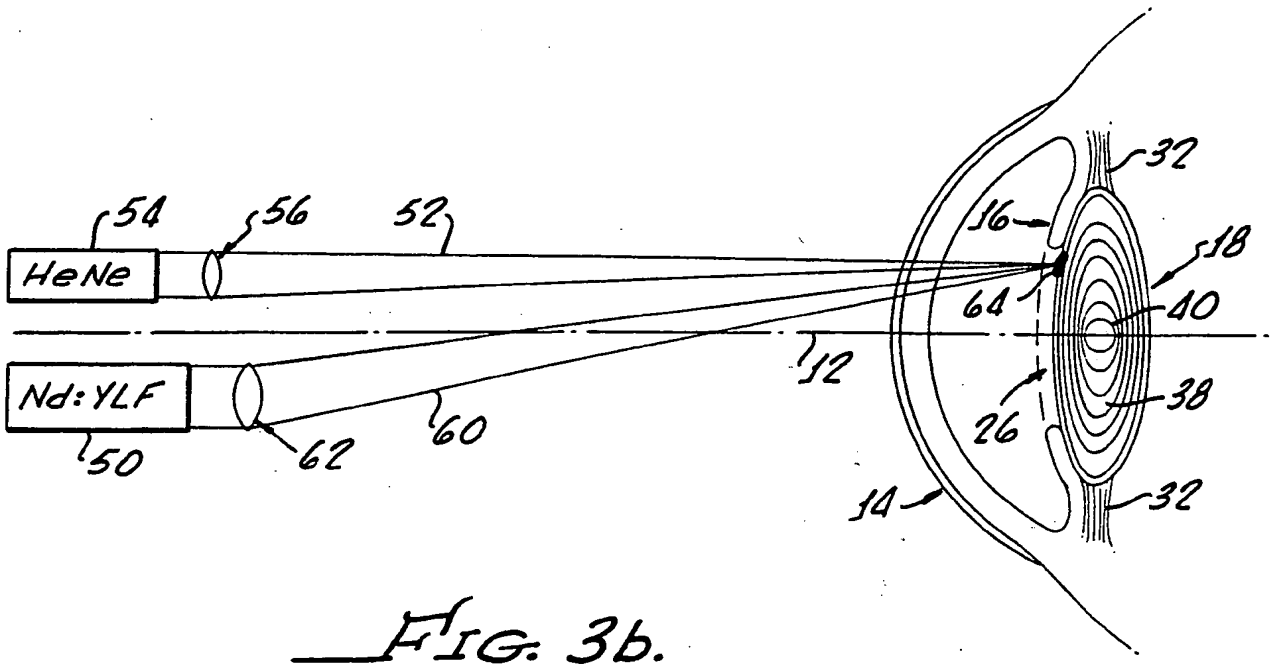


FIG. 3b.

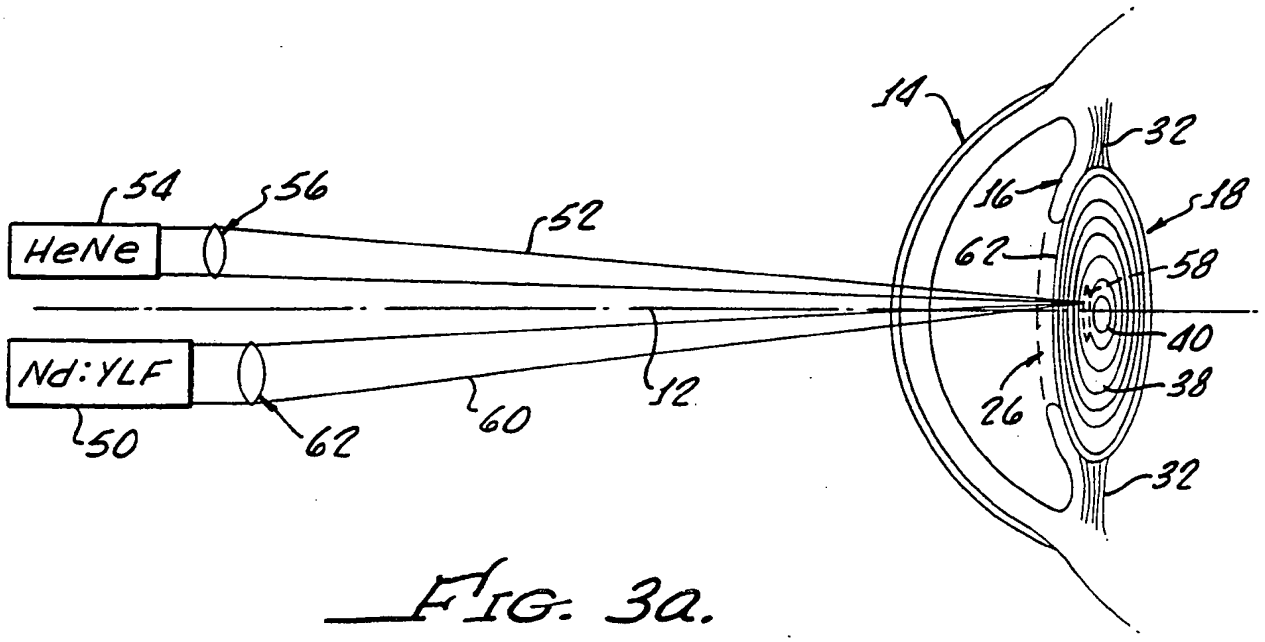


FIG. 3a.

PATENT COOPERATION TREATY

PCT

DECLARITION OF NON-ESTABLISHMENT OF INTERNATIONAL SEARCH REPORT

(PCT Article 17(2)(a) and Rule 39)

Applicant's or agent's file reference	IMPORTANT DECLARATION	Date of mailing (day/month/year)
16901AMOPCT		02/12/92
International application No.	International filing date (day/month/year)	(Earliest) Priority date (day/month/year)
PCT/US 92/07228	26/08/92	30/10/91
International Patent Classification (IPC) or both national classification and IPC	A61F9/00	
Applicant		
ALLERGAN, Inc.		

This International Searching Authority hereby declares, according to Article 17(2)(a), that **no international search report will be established** on the international application for the reasons indicated below

1. [X] The subject matter of the international application relates to:
   - a. [ ] scientific theories.
   - b. [ ] mathematical theories
   - c. [ ] plant varieties.
   - d. [ ] animal varieties.
   - e. [ ] essentially biological processes for the production of plants and animals, other than microbiological processes and the products of such processes.
   - f. [ ] schemes, rules or methods of doing business.
   - g. [ ] schemes, rules or methods of performing purely mental acts.
   - h. [ ] schemes, rules or methods of playing games.
   - i. [X] methods for treatment of the human body by surgery or therapy.
   - j. [ ] methods for treatment of the animal body by surgery or therapy.
   - k. [ ] diagnostic methods practised on the human or animal body.
   - l. [ ] mere presentations of information.
   - m. [ ] computer programs for which this International Searching Authority is not equipped to search prior art.

2. [ ] The failure of the following parts of the international application to comply with prescribed requirements prevents a meaningful search from being carried out:
   [ ] the description [ ] the claims [ ] the drawings

3. [ ] The failure of the nucleotide and/or amino acid sequence listing to comply with the prescribed requirements prevents a meaningful search from being carried out:
   [ ] it does not comply with the prescribed standard
   [ ] it is not in the prescribed machine readable form

4. Further comments: See PCT-Rule 39.1(iv)

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	

Form PCT/ISA/203 (July 1992)